POTABLE WATER

AND THE

RELATIVE EFFICIENCY OF DIFFERENT METHODS OF DETECTING IMPURITIES.

BY

CHARLES WATSON FOLKARD,

Associate Royal School of Mines.

REPRINTED FROM VAN NOSTRAND'S MAGAZINE.

NEW YORK:
D. VAN NOSTRAND, PUBLISHER,
23 MURRAY AND 27 WARREN STREET.
1882.

PREFACE.

THE acknowledged fact that there is a possible difference between *wholesome* water and that which the chemist pronounces *pure* water, is a sufficient reason for publishing this essay in its present form. That it was prepared with much skill and care, is abundantly proven by the "Discussion" by eminent authorities of the essay when originally presented to the Institution of Civil Engineers, and which is also herewith presented.

The Analysis of Potable Water, with Special Reference to Previous Sewage Contamination.

As far as the examination of mineral substances is concerned, analytical chemistry is in a very advanced state. Indeed, it may be a matter of opinion as to whether any improvement is required for practical purposes. But as regards organic chemistry, especially that branch which deals with the secretions and tissues of plants and animals, the reverse is the case, and analysts are at present groping in the dark. Nor is this to be wondered at, when the enormous number, great complexity of composition, and unstable nature of these bodies are taken into account, and also the short time that has elapsed since they were first studied. It is a comparatively simple matter to estimate the percentages of the constituents of a body, in other words to make an ultimate

analysis of it; and where one element forms but a few combinations with another, the relative amounts of the constituents determine which of the compounds is under investigation. But inasmuch as hundreds of organic compounds are made up of the same three or four elements, and in many even the proportions of these elements are nearly the same, it is obvious that ultimate analysis will not afford sufficient information to allow of the presence or absence of a certain substance being predicated. If the analyst receive the substance in a pure state, or if it be capable of purification by crystallization, distillation, &c., its physical properties of specific gravity, form, color, &c., are of great assistance in ascertaining its identity. But if a solution in water is the form in which it is received, and especially if the solution be very dilute, the difficulties are greatly increased. When, in addition, the substance itself is very prone to decomposition, and is mixed with other bodies equally unstable and equally hard to de-

tect, a degree of complexity is introduced into the investigation which makes it an almost hopeless task in the present state of chemical science.

Such are the perplexities under which the Water analyst labors, and their careful consideration may serve to account for the wide differences of opinion on this important subject. It is much to be regretted that this uncertainty should exist, and it can only be hoped that in a short time a bright light (possibly by the aid of electricity) will illumine this almost untrodden ground of research.

The author proposes to divide the subject as follows:

1. The various ways in which water becomes contaminated.

2. The methods employed by analysts to detect and determine the extent of this contamination, with an opinion as to the probable value of the results obtained by the various methods.

3. The bearing of the results of biological and microscopical research on the question.

4. The adequacy or inadequacy of the proposed remedial measures, irrigation, chemical treatment, and filtration.

1. The various ways in which water becomes contaminated.

Immediately on the condensation and precipitation of the aqueous vapor of the atmosphere as rain, the liquid dissolves more or less of every substance with which it comes in contact. Oxygen, nitrogen, carbonic acid, ammonia, and nitric acid can be detected, and these may be taken as normal constituents of rain falling on the surface of the earth or on the catchment reservoir of a town. It will also be always more or less contaminated with the excreta of animals, although reservoir water will contract but an inappreciable amount of impurity from this source.

The next stage for consideration is rain water in the form of springs. In addition to the above-mentioned bodies, spring water contains various mineral substances dissolved from the strata through or over which it has passed, the

majority if not the whole of which are innocuous in the quantities in which they exist in most specimens; together with a further amount of animal contamination, varying in nature and quantity with the character of the area, as to population and agriculture, in which the springs occur. In remote country districts the contamination of the water up to this point is very slight.

In the next stage, the rivers, there is an enormous increase of contamination. Nor is this to be wondered at, considering that rivers are the natural drains of the country, into which every particle of rain falling within their watersheds (except that evaporated from the surface) ultimately finds its way, with everything which it is capable of dissolving or suspending. Highly manured arable land, pastures with their thousands of cattle and sheep, mills, factories, village cesspools, and, lastly, town sewers, all contribute their quota of foul water; in some cases to such an extent that the river becomes an open sewer in which no

fish can live, and the exhalations from which, especially in hot climates, spread fever and death around.

The remaining sources of water to be considered are wells. In country places these may be uncontaminated, but in most cases it is far otherwise, owing to the utter want of foresight in the sanitary arrangements, the cesspool being frequently close to (and of course above the level of the water in) the well. With regard to wells in towns provided with a deep sewerage system, they are generally dry, fortunately for their owners; on the other hand, if the town be provided only with cesspools, the ground is so saturated with sewage matter from the latter that the water is totally unfit for use.

2. Having thus considered the various sources of water supply, and the nature and amount of contamination to which each is liable, the second division of the subject follows—"the methods employed by analysts to detect and determine the extent of the contamination."

The mineral constituents may at once

be dismissed, as their determination is a very simple matter; and unless they exist in enormous excess, without doubt they are practically harmless. 'I he organic substances iu solution and suspension are the most important, on acconnt of their dangerous nature, and, unfortunately, they are the ones with which the chemist is least able to deal. As yet he has been compelled to be content with the examination and estimation of the products of their decomposition—ammonia and nitrous of nitric acids—or with the determination of one or two of their constitutional elements (carbon and nitrogen). Urine *per se* is by no means a difficult substance to detect and analize; but the examination of water containing one-hundredth or one-thousandth part of urine, a week or two old, is a very different matter. So also with the solid excreta of animals on the one hand, and the same suspended in minute quantities in water on the other. In the present state of analytical chemistry it is impossible to detect either the one or the

other in those highly diluted forms. Common salt is abundant in urine, but so it is in many soils, and therefore is generally found in water; and as it is impossible to distinguish between that derived from the land and the same substance contained in sewage, the fact of its presence or absence in a sample of water is not of much importance.

Then, again, rain contains ammonia and nitric acid (if not also nitrous acid), and it becomes impracticable to detect whether these substances, when found in water, are derived from the decomposition of organic matter with which the water has been contaminated, or have simply been dissolved from the atmosphere by the rain in falling.

(*a*) The oldest process for the investigation of the organic matter in potable water is by the incineration of the solid mass left on evaporation of the sample, and it has the great advantage of simplicity. A measured quantity having been evaporated to dryness, the residual solid matter is weighed and heated, finally

to bright redness. The evaporation is usually conducted in a platinum dish in a water-bath, by which means loss by ebulition is avoided. The residue, after weighing, is heated to redness in the dish over a Bunsen flame. By this process the organic matter is burnt away, carbonic acid, nitrogen, &c., being given off. At the same time any carbonate of lime or magnesia is decomposed, the carbonic acid being expelled. To correct the error thus introduced, the ignited mass is moistened with a solution of carbonate of ammonia, by which means the quick-lime left again takes up carbonic acid equal in amount to that expelled. It was generally assumed that the magnesia did the same, but this is found not to be the case. The excess of carbonate of ammonia having been driven off by a gentle heat, the dish, with its contents, is again weighed, and the difference, amounting usually to from 2 to 6 grains per gallon, was assumed to represent the quantity of organic matter present. Unfortunately,

many water residues show a gain of weight by this treatment, and it has been conclusively proved that it is impossible to measure the quantity of organic matter by this method; but as it affords useful hints as to its nature, it cannot well be dispensed with. For instance, if, on heating, the dry residue blackens, and an offensive smell (especially one of burnt hair) is given off, the existence of nitrogenous animal substances in the water is conclusive, and in nine cases out of ten these substances are animal excreta of recent origin. If, on the other hand, there be little or no liberation of carbon (and consequent blackening when the water residue is heated), and if sparks be noticed, or the peculiar smell of burning touch-paper be perceived, organic matter and nitrates or nitrites are indicated, by the mutual reactions of which, at high temperatures, these effects are produced. From this it can be inferred that part of the organic matter has been oxidized and converted into the harmless salts of nitric

or nitrous acid, while another portion remains undestroyed in the water.

Again, if the blackening produced by ignition speedily disappear by contact with the air, the organic substance from which the carbon was liberated was most probably of vegetable origin, and therefore less dangerous to the animal economy. If, on the other hand, the carbon burns off very slowly, it was probably derived from animal substances, which are the most objectionable forms of organic impurities.

It will be as well to point out at once, however, that there is a fundamental objection to the process in the very fact of the evaporation of the water. There is no evidence to show that such unstable bodies are not partially, or in some cases totally, destroyed during the process. Indeed, with one of them (urea) this is known to be the case.

(*b*) The process introduced by Drs. Frankland and Armstrong is open to the same objection, a prolonged evaporation of the water, and although this is effected

at a temperature below the boiling point, it is complicated, and in all probability rendered far more destructive to the organic matter which it has been devised to estimate, by the presence of mineral acids during the evaporation. The residual solid matter is submitted to ultimate organic analysis, by which the amount of nitrogen and carbon is computed. The process is as follows: The water residue is intimately mixed with oxide of copper, and transferred to a tube, ½-inch in diameter and 12 or 15 inches long, which is then completely exhausted of air by a Sprengel pump. The tube, with its contents, is heated to bright redness, till no more gas is evolved, and the products of the reaction (consisting of steam, nitrogen, and carbonic acid) are pumped out into a tube full of mercury standing in a pneumatic trough. The steam is condensed, but the nitrogen and carbonic acid are separated and measured, and from the number of cubic inches of each gas obtained, the weights of nitrogen and of carbonic acid (and from that, of the

carbon itself) are easily deduced. At a red heat, oxide of copper decomposes all organic substances, animal or vegetable, transforming their carbon into carbonic acid gas, and their hydrogen into aqueous vapor, while the nitrogen is liberated in the free state, also as gas. The presence of mineral acid during the evaporation is necessary to drive off the carbonic acid, usually a carbonate of lime or magnesia, which, if it were not previously got rid of, would be expelled by the red heat and mix with the carbonic acid formed from the organic matter, so causing an error. The nitrogen and carbonic acid collected are measured over mercury; the carbonic acid is then absorbed by a solution of potash, and the gas left, which is nitrogen, is measured, the difference being the carbonic acid.

Having thus obtained the weights of carbon and of nitrogen existing as organic matter in a certain volume of the water, or rather that portion of the organic matter which has not been decomposed by the prolonged heating with

mineral acid, the quality of the sample is inferred from their amount, and from the ratio which they bear to one another, it being assumed that the greater the ratio of nitrogen to carbon, the more highly organized, and therefore the more dangerous, is the organic impurity. A very little thought, hovever, will suffice to show that the information thus obtained is only of the most general character. Assuming, then, that a high ratio of nitrogen to carbon is characteristic of the organic matter in a dangerously polluted water, if a further pollution by organic substances, in which the nitrogen-carbon ratio is small, take place, the doubly-fouled water would be returned as the less dangerous. This example shows the weak point of the process, or rather of the deductions made from the data furnished by it, namely, the application to a mixture of substances (the organic impurities of water) of reasoning which can, properly speaking, only be applied to the case of a single substance.

(*c*) A process which has found much

favor amongst analytical chemists is the so-called albumenoid ammonia method. It is assumed that the nitrogenous organic impurities in water are the most dangerous, which is probably the case, and the process professes to estimate the quantity of these substances, by determining the amount of ammonia produced by their decomposition when boiled with an alkaline solution of permanganate of potash. A glass retort and Liebig's condenser are used, the amount of ammonia formed being estimated in the distillate. This is effected by making up solutions of ammonia of different known strengths, and observing which of them gives a brown coloration of the same intensity as the sample under trial, when mixed with a solution of iodide of mercury and potassium.

No previous evaporation of the water is necessary, which is undoubtedly a great advantage over the first two processes; but inasmuch as this method is only an imperfect ultimate analysis, even less knowledge is obtained than by the second

method, though this has the great advantages of ease of manipulation and rapidity, the results being in all probability of equal value for practical purposes.

(*d*) The last to be considered is the permanganate process, in which the amount of permanganate of potash required to oxidize the organic matter is ascertained. This is supposed to be an index of the quantity of organic matter in the water, and it would be so if only one form were present; but inasmuch as there may be dozens of different substances in solution or suspension, some hurtful, some harmless, some susceptible of much oxidation, some almost, or even totally, unacted upon by permanganate (and so far as is known the most dangerous may consume the least oxygen, or none at all), it is obvious that this method also will not afford results the accuracy and reliability of which are above suspicion.

The estimation of the ammonia, nitric, and nitrous acids in water, is a simple

problem in mineral analysis, of which it will be unnecessary to treat in detail.

Having briefly reviewed the advantages and defects of the various processes for estimating the nature and the amount of the organic contaminations of potable water, it seems impossible to come to any other conclusion than that the subject is as yet beyond the scope of analytical chemistry. Even granting that the assumptions of the advocates of the different processes are correct, it is evident that their deductions are illogical, reasoning fit for a single substance only being applied to a mixture of substances.

As regards inorganic analysis the processes can be checked by experimenting on weighed quantities of pure substance purposely mixed with other bodies. If the same amount is recovered (within the small limits of errors of experiment), the process is evidently a reliable one; but with the impurities of water this is impossible, and the information afforded by the methods now in use is of the vaguest and most general character, so

far as the wholesomeness or the reverse of a given sample is concerned, although by one of them (*b*) it is possible to determine the minimum amount of contamination which has taken place since the water was precipitated as rain. For this purpose the whole of the nitrogen existing in any form in the water is determined, but this does not include free or gaseous nitrogen dissolved from the atmosphere, which is expelled in the preliminary evaporation, and therefore does not affect the results, viz.:

Nitrogen in the form of ammonia.
" " " organic matter.
" " " nitric and nitrous acid.

Deducting from this total the average amount of nitrogen in the form of ammonia which exists in rain as it falls, the residue is the minimum quantity which the water has acquired from animal and vegetable contamination. It is not necessarily the total quantity acquired, because some may have been abstracted by growing plants, &c.

No definite impression is conveyed to the mind by the statement that there are in a sample of water so many parts per 100,000 of nitrogen, derived from animal and vegetable detritus. A standard of contamination therefore becomes desirable, and the one which has been proposed is the amount of nitrogen per 100,000 parts of average filtered London sewage. By simple proportion it is then easy to calculate the degree of contamination of any water; that is as if 100,000 parts of pure water had been mixed with so many parts of London sewage.

It must be borne in mind, however, that no distinction is made in this case between nitrogen present as organic compounds of more or less dangerous character, and nitrogen existing in the harmless inorganic salts of ammonia, nitrous and nitric acids. This latter form of nitrogen represents more or less originally dangerous organic impurities, which have been gradually resolved by oxidation or fermentation into the inorganic forms. Consequently a deep well-water, *e.g.* from

the Chalk, may be returned with perfect accuracy as having received as much or more "previous sewage contamination" than a shallow well or river, and yet in the former case the water may be absolutely innocuous (all its organic impurities having been destroyed by oxidation in the pores of the Chalk), whereas the well or river water, with its recent contamination, may be quite the reverse.

The first stage in the oxidation of nitrogenous organic matter is the production therefrom of ammonia, which by further oxidation is converted into nitrous or nitric acid.

3. Chemists being powerless to help the sanitarian in discriminating between wholesome and unwholesome water, it seems essential to consider what can be done by microscopists and biologists. In the first place it is an ascertained fact, proved beyond the possibility of doubt, that mere dilution, how far soever it be carried, does not render inoperative the specific action of living germs, and so marvelous is the rapidity of reproduc-

tion of low forms of life, that if the environment or conditions are favorable to their growth, it matters little whether the liquid is stocked with ten or with ten thousand at the commencement. In a few days there will be as many as can exist, the only difference being that the sample which received most of the contaminating liquid will arrive at the maximum a few hours before the other. There can be little doubt but that the same thing occurs in the case of the human subject. Provided the individual is sufficiently weakly or unhealthy, it is of small importance whether he receive 1,000 or 1,000,000 parts of infectious matter (whether in the form of organized germs or not is immaterial), and consequently 1 part of infected sewage containing the dejecta of persons suffering from zymotic disease mixed with 1,000,000 parts of water will be nearly as dangerous to him as 1 part per 1,000. Of course the less contaminated water would probably not affect a person in more robust health who might succumb to the use of the highly

contaminated sample; but what the author wishes to insist upon is that it will be impossible to banish zymotic disease from a town whose water-supply has been contaminated with the dejecta of patients suffering from that disease. The very weakly will contract it from the almost inappreciable amount of infection contained in the water, and from them it will spread to those who have resisted the poison in its diluted state.

Secondly, the germs which cause or accompany disease are endowed with the most persistent vitality, and are capable of withstanding heat, cold, moisture, drought, and even chemical agents, to a marvelous extent. So difficult is it to destroy them that for many years the now exploded doctrine of spontaneous generation found talented supporters, who relied on their own carefully conducted experiments to prove the theory, all which experiments were subsequently found to have been rendered illusory by the astounding vitality of these low forms of life.

Bearing in mind, then, the influence, or rather the absence of appreciable influence, of mere dilution, and the difficulty with which infectious matter is destroyed, the conclusion that once contaminated water never purifies itself sufficiently to be safe for dietetic purposes becomes inevitable; and as chemical analysis fails to give reliable evidence as to its fitness or the reverse, the author believes that the only safe test of the wholesomeness of a given water is by tracing it to its source, and ascertaining that no objectionable impurities gain access to it.

This will at once condemn all rivers flowing through a populous country; and if it be considered that a river is the natural drain of a district into which everything soluble or suspensible in water ultimately finds its way, it will not be a matter of wonder that this should be the case. No Conservancy Board can keep pollution out of a river; it must receive all the rain falling within the limits of its watershed

(excepting, of course, that which is evaporated), together with the overflowings of cesspools and the sewage of towns within the same area. It is part of the great circulatory system of the earth which it is vain for man to attempt to control.

This being so, it is evident that rivers, except near their source, can only afford polluted water, and a problem utterly insoluble by man is presented, viz., the purification of foul water on a large scale. The chemist can do it in the laboratory, but only by adopting a similar process to that by which it is effected in Nature—fixation of the ammonia in the soil or its oxidation to nitric acid, followed by distillation by the heat of the sun. Take, for example, the case of a river with a town of 50,000 inhabitants on its banks. If supplied with water at high pressure and sewered, the amount of foul water discharged into the river will be about 1,000,000 gallons daily, irrespective of the rainfall, which will bring with it the washings of the streets,

&c. Taking the total flow of the river at 500,000,000 gallons, and supposing that the water is perfectly pure when it reaches the town, there will be a mixture of 1 part of sewage in 500 parts of clean water, for the inhabitants of the next town to drink. Take now an infected liquid and add 1 part to 500 or even to 500,000 parts of liquid susceptible of infection. The mixture will swarm with low organisms and become putrid in a few days, provided only the conditions are favorable. And what may be expected to happen to the unfortunate inhabitants of the lower town? Simply this, that the strong and healthy will have sufficient vitality to throw off the poison, but the weak and sickly will succumb, inoculated by the dejecta of zymotic patients in the upper town. Such a state of things seems hardly possible in a civilized community.

The above is no fanciful picture. The experiment was tried on the inhabitants of a town in Surrey, unwittingly it is true, but on that account the result is all

the more reliable. An epidemic broke out, and the consequent investigation revealed the cause in all its loathsome details. Fortunately for mankind at large the relation in this case between cause and effect was distinctly traceable, but in the great majority of cases this is out of the question.

There is not the least evidence to show that foul water is rendered wholesome by flowing 50 or 100 miles; indeed, all experiments point in the opposite direction, on account of the persistent vitality of the organisms which accompany zymotic disease, and of the utter failure of dilution to disarm these potent germs of corruption and death.

4. The possibility of abating these evils, otherwise than by a radical change, will now be investigated.

It is often asserted that as the sewage of towns is "treated" by chemical agents before being passed into the river, the previous objections do not hold good. But inasmuch as most of the soluble matters are unaffected by

the process, and in view of the great vitality of the low organisms, it is open to doubt if the latter are destroyed by the agents used. Even the irrigation process, the most natural, simple, and effective where the locality is suitable, is liable to the serious objection that part of the sewage may flow direct to the river through accidental channels, without filtration through the soil.

Putting, however, all this aside, those who are practically acquainted with the subject are perfectly aware that no sewerage system yet carried out (even though its cost be reckoned by millions sterling) can cope with storm water. As a necessary consequence the by-pass must be opened, the sewage allowed to flow direct into the stream, and the inhabitants of the town below regaled with a more than ordinarily filthy beverage for the next few days. This again is no fanciful statement; it can be seen in operation more or less frequently all over the country.

Filtration is another remedy put for-

wholesome water, nor was the pure water of the chemist always wholesome. He differed from the author, however, in regard to some points, as, for instance, that river exhalations were injurious, spreading fever and death. Mr. Latham maintained, on the contrary, that there was no evidence to show that exhalations from polluted rivers had proved to be detrimental to health. Every authority agreed upon the point that malaria was never extricated from water surfaces, and in malarious countries it was not until the water had disappeared that malaria became manifest. In this country there were sufficient examples to show that the exhalations from foul rivers were not unwholesome. He might instance the case of the year 1858, before the sewage was discharged lower down the Thames, when the foul tide flowed through London. It was a year of drought, and great stench prevailed along the banks of the river, but the mortality tables did not indicate that the districts bordering upon the Thames had in any way suf-

fered. He might quote other towns, like Norwich, where the river Wensum was formerly polluted in a similar way to the Thames, thereby causing a great nuisance to the villages below, yet not one of them had suffered in health from the exhalations. He could not agree with the author that there was no evidence to show that foul water was rendered wholesome by flowing 50 or 100 miles, and that dilute sewage (meaning, he presumed, water contaminated by sewage) could never be made safe for dietetic purposes. Nor could he agree with the statement as to storm-water overflows, but as that was no part of the question under discussion he would not dwell upon it. The subject of the paper was one of considerable importance to those engaged in questions of water-supply, for he regarded the future improvement of the sanitary condition of the country as being almost entirely dependent upon the attention which must be paid to the selection of water-supplies, and the means to be adopted for effecting the

purification of water. At present, if engineers were to take the dictum of some chemists, it was quite clear that there was no water-supply fit for use. In the sixth report of the Rivers Pollution Commission it was stated "that it is in vain to look to the atmosphere for a supply of water pure enough for dietetic purposes." Now, as all sources of water-supply were due to atmospheric causes, and the author had stated that it was useless to look for purification by any mode which would be adopted by the engineer, such as filtration or percolation (because the germs, he said, could pass a thousand abreast through a filter), therefore if the rain-water was impure as its source how could it ever be purified? Indeed, if the water-supply of the country were in such a lamentable condition, the wonder was that there was any one living to describe the state of things. The chemist could not discover what were the dangerous impurities in water. In order to supply a deficiency in the paper, or the furnishing of facts

to substantiate the proposition put forward, he would read an answer given to a question by Dr. E. Frankland in the Middlesborough water case. Q. 5,052. "And do you think it most unsafe to supply a large population from water which has been impregnated with the excreta of patients suffering from various diseases? I do; although chemical analysis may fail to detect anything unusual in the water, because I have myself mixed 1 volume of the dejection of a patient dying of cholera with 1,000 volumes of good water, and have submitted it to analysis, and have been unable to detect anything unusual in the water; chemical analysis is unable to detect these small quantities of morbific matter, which are calculated to transmit disease to people drinking the water." That was the opinion of one of the most distinguished chemists of the day. With reference to the amount of contamination in water capable of producing disease, he would quote from a little book on "Portable Water," by Mr. Charles

Ekin, F.C.S. Mr. Ekin stated, p. 15, "Waters which have undoubtedly given rise to typhoid fever have been found by the writer over and over again not to contain more than 0.05 part of albuminoid ammonia in 1,000,000, and which notwithstanding their containing a large excess of nitrates have been passed by analysts of undoubted ability as being fit for drinking purposes." In an outbreak of typhoid fever at Guilford in 1867, it was clearly shown, on analyzing the water which was the supposed cause of the outbreak, that it was purer than other samples on which no suspicion rested. In all the calculations of the chemist it appeared to be only a question of degree; they could neither distinguish between the matters which were found in the water, nor the source from which they were derived. If a certain quantity of organic matter, whether sewage or the "germs" of disease, was mixed in the proportion of 1 part to 4 parts of pure water the chemist would call the mixture good water. On the 29th of November,

1875, when an epidemic of typhoid fever was rife in Croydon, there were great suspicions respecting the quality of the water supply. The level of the water in the well at the waterworks was lowered by pumping, and three samples of water were collected as they trickled into the well. They were submitted to Professor Wanklyn, who gave the amount of albuminoid ammonia in the respective samples as 0.14, 0.26, 0.22 per million parts. He stated that two samples were highly charged with sewage and that the other sample was not pure; but in the well the water contained 0.04 of albuminoid ammonia, and he added that that was water of the purest class. Thus, from the examination of the chemist, it appeared that it was quite possible to mix water which the chemist condemned as impure with that which was pure, and the result woald be that the water came out as belonging to the purest class. As to the question of albuminoid ammonia being the means of showmg whether water was wholesome or not, he might

mention that about the end of the year 1880 the chairman of the Nantwich Local Board of Health told him that the Medical Officer of health of Mid-Cheshire had condemned the public water-supply of the town as totally unfit for domestic use. The supply was taken from a natural lake called "Baddiley Mere," and was brought a distance of 4½ miles by gravitation into the town. The authorities had only power to draw off to a certain depth the top-water. It appeared, from an examination in October, 1880, that the amount of free ammonia was 0.21, and of albuminoid ammonia 0.44 in a million parts in the unfiltered town water, but after efficient filtration the amount of free ammonia was 0.08, and of albuminoid ammonia 0.38. The chemist stated in regard to it, "Organic matter in great excess, rendering water dangerous and unwholesome; the contamination not recent; filtration of little use." In the month of November a second analysis was made, and the results were a little better. The filtered water showed 0.32

part of albuminoid ammonia instead of 0.38, and the remark by the chemist was "the least said about these the better." The report also contained the analyses of the well-waters in use in the town, which were, without exception, very unsatisfactory from the chemist's point of view. He then inquired of the Chairman of the Local Board what was the state of health in the town; he was informed that it was never better, and he therefore advised the Chairman of the Board that as long as the public health was so satisfactory to pay no attention to the alarming reports of the chemist. The Registrar-General had since issued four quarterly reports on the health of the district, namely, for the fourth quarter of 1880 (embracing the period in question), and three quarters in 1881. During the year there had been one death from scarlet fever, two from diarrhœa, and one from fever, the population of the district at the census of 1881 being 11,192. The zymotic death rate in the year was but 0.35 per thousand, or about

one-tenth the zymotic death rate of London in the same period, and was one of the lowest that it was possible to conceive in any district, and yet the district was supplied with "dangerous and unwholesome" water.

The following table showed the relative amount of average impurity in the water supplies of London, as ascertained by Dr. Frankland, together with the death rates in each year. The investigation was begun in 1868, when the impurities in the Thames were called 1,000 parts. With that number the relative amount of impurity in other years and other sources of water supply was compared. The numbers were proportional.

The highest annual death rate, and the highest zymotic death rate in London (1871) occurred when the impurities in the Thames and Lee were below the average, and the waters of the deep wells were freest from impurities. The high fever death rate in 1868 occurred when the impurities in all the sources of water supply were below the average. The low-

Year.	Proportion of organic impurity in Thames water delivered in London.	Proportion of organic impurity present in Lee water as delivered in London.	Proportion of organic impurity in deep well water as delivered in London.	Annual death rate of London per 1,000.	Death rate of London from seven principal zymotic diseases per 1,000.	Death rate of London from fever per 1,000.
1868	1,000	484	254	23.5	4.82	0.78
1869	1,016	618	312	24.6	5.57	0.78
1870	795	550	246	24.1	5.19	0.63
1871	928	604	150	24.7	5.97	0.54
1872	1,243	819	221	21.4	3.84	0.41
1873	917	693	250	22.4	3.32	0.45
1874	933	583	287	22.4	3.29	0.46
1875	1,030	751	250	23.5	3.87	0.37
1876	903	562	246	22.0	3.56	0.33
1877	907	596	243	21.5	3.43	0.35
1878	1,056	747	323	23.0	4.05	0.37
1879	1,175	954	387	22.7	3.25	0.29
1880	1,263	1,143	393	21.6	3.64	0.24
Averages.	1,013	708	273	22.9	4.14	0.46

est death rate in London occurred in 1872, when the impurities in the Thames and Lee were above the average; and in 1880, when the death rate was low, all the sources of water supply contained impurities in excess. The zymotic death rate of London was lowest in 1879, when

all the sources of water supply contained impurities above the average; and under similar circumstances the fever death rate in London was lowest in 1880. In the year 1870 the waters of the Thames and Lee contained the least amount of impurity in all sources of water supply, yet during the same period the death rate had steadily declined. He did not wish to impugn the character of the chemists; they were men of great honesty and ability, and they themselves confessed the things to which he had referred. Dr. Frankland had admitted that small quantities of morbific matter could not be detected by chemical analysis. But there was a vast amount of ignorance among the general public on the subject, and he had himself to combat it to a great extent in the case of investigations made at Croydon. Dr. M. F. Anderson, in a letter to the *Sanitary Record* of February 3d, 1877, stated, with regard to the albuminoid ammonia process, that he had "never been able to obtain conclusive evidence that the dan-

gerous elements of bad water are evolved as albuminoid ammonia;" and he added, "My observations tend rather to the belief that typhoid germs are easily oxidized, and do not yield up their nitrogen as ammonia, but as nitro-oxides." That rather went back to the question of previous sewage contamination, which seemed to be almost a phantom of the past, as it appeared to have been abandoned by its author; but he thought there was something in it, because it certainly showed the progressive impurities that took place in water. From the report of the Royal Commission on Water Supply, it was shown that in the district from Caterham to Croydon there was a very considrable increase in the previous sewage contamination; or a progressive degree of deterioration in the water had taken place. Those who were conversant with the district would know that there must have been such deterioration because the valley was thickly populated; it had two waterworks in its upper part; it had no sewers

whatever; all the water pumped passed through cesspools, and by a sort of circulating system all the impurity was carried back into the soil, and which flowed down the valley, and what was not used naturally found its outlet in the river Wandle. It was evident that in a valley of that kind there must be a natural deterioration; but unfortunately the chemists had never been able to find it, for although the previous sewage contamination had enormously increased, that counted for nothing with the chemist at the present day. In such a district, however, what might have been proved to be serious sewage contamination was very likely to become present sewage contamination of the most dangerous description. In the epidemic of fever in Croydon in 1875 the water had been analyzed over and over again; but it was always pronounced to be water of the purest class; yet in that year one person in forty-two living in the Croydon water district suffered from typhoid fever as against one in eight hundred and nine

in the district immediately outside, and in many instances the same sewers were used in common. Numerous investigations had taken place in connection with the subject, and he had himself inquired into it, feeling that it was an utter disgrace to the sanitary science of the day that those repeated epidemics in Croydon should escape detection. They had always been referred to the same cause—sewer gas; but he believed that he should be able, from the facts he had collected, to throw a very different light upon the subject. If repeated coincidences were tantamount to positive proof, he believed he should be able to show that certain meteorological conditions were connected with the outbreak of every one of those epidemics, which came into operation only at particular times. One thing was certain, that at all times the fever death-rate in Croydon was inversely proportionate to the quantity of water flowing from the district. The author had stated that it was necessary to trace water to its source. But that had been the diffi-

culty in Croydon. The late Dr. Letheby, who analyzed the Croydon water, found it to be good; but that did not satisfy his mind, for he distinctly reported to the authorities of the Friends' school, by whom he had been called in, that the water-supply was dangerous by reason of its source in the center of the town. Mr. Latham at one period held the same views as Dr. Buchanan, who reported on this outbreak in 1876, that fever was caused by sewer gas; but he had seen reason to alter his opinion. The difficulty, however, had been to trace the water; but during the past year, not only had the movement of the subsoil water been traced, thanks to the ability of a chemist in the city, but Mr. Latham had been able to bring the matter under direct calculation, and to show the quantity of the immediate subsoil water getting into the Croydon wells. The case was this. The wells furnishing the supply of water to the town had been sunk and bored into the porous soil, consisting of gravel and chalk. They were lined

with iron cylinders for a certain distance from the surface, and the subsoil water outside the wells was supposed to be shut out by the iron lining; yet when pumping went on every fluctuation within the wells was discernible in the subsoil water outside. It had been stated by an eminent engineer that these fluctuations simply meant that there was a sympathy between the waters. Other theories had been advanced, one of which might be called the "band-box" theory. It was stated that when the water outside the well subsided, it did not flow into the well, but that it was like a tier of band-boxes, the bottom one might be pulled out, but the top one would not come down. Then it had been referred to pulsations, or waves caused by the agitation of pumping. Fortunately, for the sake of science, on the occurrence of a bourne flow at Croydon, early in 1881, he received a communication from Mr. G. W. Wigner, that if Mr. Latham would collect the samples of water during the bourne-flow he would be happy to investigate

the matter from a chemical point of view. After the collection of the samples, Mr. Wigner wrote to him that it would be desirable, as the next step, to trace the movement of the underground water by means of lithium. He saw at once that this was exactly what was required to ascertain whether or not there was a connection between the immediate subsoil-water outside the wells and the water within the wells, and if the fluctuations which had been observed were indicative of this connection. Before making any experiments, however, he put two questions to Mr. Wigner, one of which was whether the material was innocuous, to which the reply was, "perfectly innocuous," and the other whether small quantities of the material could be detected, to which Mr. Wigner replied, "Yes, $\frac{1}{3000000}$ part of a grain can be found in a gallon of water by spectrum analysis, but in no other way." Three experiments were made at various distances from the Croydon Water Works wells, and it had been shown that the lithia moved in

all directions, exactly at the same rate, into the wells, as the fluctuations in the water caused by pumping had been found to move. Lithia afforded, therefore, a mode of readily detecting the movement of water. It was admitted that the subsoil-water at Croydon was in direct communication with the sewers, and if it got into the wells, it was a source of danger. There were great difficulties in carrying out the investigation, because the lithia could only be detected by spectrum analysis. Again, when material of that kind was put into the soil, a portion of it remained and was with difficulty got rid of, for when an acid salt had been put into a chalk soil, a portion of the acid combined with the chalk, and a less soluble salt of lithia remained in the soil. Investigations of this kind should only be carried out under the advice, and with the assistance of a chemist. He did not think that Nature had left mankind in the unguarded and unprotected state described by the author, liable at any moment to have

their lives jeopardized from impurities in water. There were means, no doubt, by which the very foulest water could be purified, and those means were more active in a river than in any other source of water supply. He would refer to the statement of Mr. T. Hawksley, Past-President Inst. C.E., with reference to the outbreak of cholera in 1848–9, recorded in the report of the Commissioners of Water Supply, that in those years cholera was epidemic at Bilston, Wolverhampton, or in the Black Country; and so violent was it that people encamped outside the towns. During the whole of that time the sewage of those infected places flowed into the Tame, and, after a course of 20 miles down the river, it was used for the water supply of Birmingham, and there was no cholera in Birmingham. It was therefore clearly shown that by the simple flow of the water that distance the morbific elements had been destroyed. He might also refer to a more recent period, 1875–76, when typhoid fever was prevalent

in Croydon, there being at least two thousand cases in those two years, during which time the whole of the sewage of the town was passed on to the farm at Beddington. There was a cluster of eighty houses lying between the farm and the Wandle, all inhabited, their only water supply being from shallow wells, and the proximity of the application of the sewage upon the farm caused the water in these wells to fluctuate, yet the elements of disease were destroyed so that there was not a single case of typhoid in any one of those houses, or even in the valley down to Merton, containing a considerable number of inhabitants. There again it was shown that Nature had provided safeguards; and it was the duty of engineers to copy the examples of Nature, and to treat water in the way in which Nature treated it, in order that the foulest and most dangerous impurities might be destroyed or removed from it.

Dr. Tidy said, in discussing the question of water supply, it was important to

grasp its many-sidedness. When it was desired to supply water to a town, various possible sources were selected, and samples were sent to a chemist, whose duty it was to analyze them. It was not for the chemist, however, to say whether the water was pure or impure. To him, pure water was hydrogen and oxygen, nothing else. To him, 1 cubic inch of dissolved gas, or 1 grain of dissolved matter, were impurities. The chemist had only to say what was the composition of the water submitted. From the chemist it passed to the sanitarian, the medical man, whose view of the subject was essentially different from that of the chemist. With the analysis in his hand, he had to ask himself if the water was likely to be a proper one for the supply of the town for which it was proposed. He could not experiment with the water, but he endeavored to ascertain where waters of a similar kind had been supplied, and what had been the result. That was the medical aspect of the question. It then passed to the engineer. It

having been decided that the water was good, the engineer asked himself, "Is there sufficient to supply the town, and are the conditions such that it can be delivered at a moderate cost?" That was the engineering aspect of the question. It was essential to his purpose to separate these three. In criticising the paper, perhaps somewhat severely, he might be permitted to say that he had had some experience in water analysis. Without reference to the time during which he had been in practice for himself, he had, during the many years that he had assisted the late Dr. Letheby, made nearly four thousand analyses of water with his own hands; and as a medical man he had also had something to do with the sanitary aspects of the question. He would not discuss the various processes of water analysis, which he had himself dealt with at considerable length elsewhere. The author had stated that chemists were "powerless to help the sanitarian in discriminating between wholesome and unwholesome water." Dr. Tidy did not

pretend to say that the chemist could do everything, but he maintained that, given a reliable analysis of water, the chemist, or rather the sanitarian, was able to speak with almost unhesitating certainty in bringing it to bear on the sanitary question. What were the means by which to arrive at a true chemical knowledge of the composition and properties of water? He admitted, with the author, that the varieties of organic matter in potable water were somewhat numerous; chemists therefore, did not conduct a water analysis with the same certainty as they did a quantitative analysis of a body, with the exact constitution and composition of which they were familiar; but considering that two out of the four processes described in the paper, vastly different as they were in their action, closely agreed in their results, he thought the public might reasonably have some faith in these as a means for estimating the organic matter in potable water. As he had shown before the Chemical Society, with reference

to nearly two thousand cases of water analysis treated by the combustion process of Dr. Frankland, and by what Dr. Tidy had called the oxygen and others the permanganate process, the actual results were as nearly as possible identical. A report would shortly be issued by himself, Dr. Odling, and Mr. Crookes, on London water. No fewer than three hundred waters had been examined by both these processes, and by means of a series of wave diagrams it would be shown how closely they agreed in the story they had to tell. The author's statement that the chemist was powerless to help the sanatarian was a very strange one, coming from a chemist. What were the reasons he assigned for this powerlessness? In the first place he stated that "it is an ascertained fact, proved beyond possibility of doubt, that mere dilution, how far soever it be carried, does not render inoperative the specific action of living germs" (p. 24). His second reason was that "the germs which cause or accompany disease are en-

dowed with the most persistent vitality, and are capable of withstanding heat, cold, moisture, drought, and even chemical agents, to a marvelous extent" (p. 26). That was all very well, but where were the germs? In only three diseases, pig-typhoid, remittent fever, and splenic fever, had anything of that nature been detected. No such thing as a typhoid germ had been discovered. One could no more analyze a water for the germ of typhoid, than one could analyze the brain for an idea. Not only, however, did the author speak of germs as though they were tangible, but he had fixed the conditions of the life of a thing the very existence of which had never been proved. As to wholesomeness, the author expressed his belief that the only safe test was by tracing the water to its source. What source? He doubted whether there was a particle of water in creation that had not passed through an animal body once or more. For himself, looking at the subject as a medical man and as a chem-

ist, he believed the true test was not what the water was, miles off, but what it was at the place at which it was proposed to be taken for supply. That was the practical method of testing it, and it was a method always adopted in other matters. Engineers should not trouble themselves about what the water was 50 miles off, or fifty years ago, but consider what it was at the time and the place where it was proposed to take it. The author, naturally, with his views, condemned all rivers. He did not mince the matter, but said, "This will at once condemn all rivers flowing through a populous country" (p. 27). And he added, by way of illustration, "Take, for example, the case of a river with a town of 50,000 inhabitants on its banks. If supplied with water at high pressure and sewered, the amount of foul water discharged into the river will be about 1,000,000 gallons daily, irrespective of the rain-fall, which will bring with it the washings of the streets, &c. Taking the total flow of the river at 500,000,000 gallons, and suppos-

ing that the water is perfectly pure when it reaches the town, there will be a mixture of 1 part of sewage in 500 parts of clean water, for the inhabitants of the next town to drink. Take now an infected liquid and add 1 part to 500, or even to 500,000 parts of liquid susceptible of infection. The mixture will swarm with lop organisms and become putrid in few days, provided only the conditions are favorable" (p. 28). Then he asked, "What may be expected to happen to the unfortunate inhabitants of the lower town? Simply this, that the strong and healthy will have sufficient vitality to throw off the poison, but the weak and sickly will succumb, inoculated by the dejecta of zymotic patients in the upper town." "The above," said the author, "is no fanciful picture." Fanciful was not the word for it, and he hardly knew a word to express it, but certainly a more far-fetched picture, a more unbridled effort of the imagination, he had never come across. He wished to ask the author to explain how it was that, in the

case of towns affected with cholera on the banks of rivers, having regard to the period at which the outbreak of cholera occurred in those towns, the disease had invariably gone up the river and not down. He challenged the author to produce a case in which the passage of cholera had been without a break down a river. The only case given in the paper of injury from river water was one in which the experiment of drinking polluted water had been tried on the inhabitants of a town in Surrey. He thought he knew the town to which the author referred, and if he was right in his presumption, the case was one in which he had been himself consulted professionally, and he believed also Dr. Frankland. They had both written a report, and he was prepared to show if necessary, that the illustration in question had nothing whatever to do with the subject. The author had further stated that there was not the least evidence to show that foul water was rendered wholesome by flowing 50 or 100 miles.

Dr. Tidy maintained that a distance of 10 miles was sufficient for the self-purification of water under proper conditions. A few weeks ago Dr. Dupré and himself had seen a wonderful illustration of the self-purification of water within a very much shorter distance. Turning to the sanitary aspect of the question, he would remind the members that in England there was a large number of towns supplied with well water, and a large number supplied with river water. He had taken the death statistics for ten years of thirty-six of the largest towns in England, eighteen being supplied by deep well water, and eighteen by river water. The eighteen towns supplied by well water had a population of 889,340, and the eighteen towns supplied by river water had a population of 911,742. The average death rate of the towns supplied by wells was 22.72 per thousand, and the average death rate of the towns supplied by river water was 22.66 per thousand. In fever and some other diseases there was (except in certain cases that could

have nothing to do with the water) a decided advantage on the side of rivers. It might be said that he had taken a number of towns indiscriminately and mixed them up together. To meet that observation he had examined the death statistics of London, as Mr. Baldwin Latham had done. He had gone carefully over Mr. Latham's figures, brought them down to the latest date, and elaborated them somewhat more fully. London was supplied by eight companies, five of which derived their supply from the Thames, one from the Lee entirely, and one from the Lee and from wells (the New River Company), and lastly, one that derived its supply exclusively from deep wells in the Chalk. The death rate for ten years of parts supplied by river water was 21.57, whilst that of the places supplied by deep chalk wells was 21.48. He had gone through the various diseases, and had found that while certain diseases, such as croup (which he thought could scarcely be traced to water), appeared to be a little

more prevalent in the river districts, certain other zymotic diseases were somewhat in excess in the districts supplied by wells. It had been proved before the Duke of Richmond's Commission by the experiments of Dr. Frankland and Dr. Odling jointly, and these experiments had been since repeated, that at Hampton the river contained if anything less organic matter than the water at Lechlade, where the Thames first assumed the condition of a river. That water purified itself in a running river he was as certain of as he was of his own existence. And this self-purification was effected first by the process of subsidence, the solid matter in the water being carried down; secondly, by the process of oxidation (the oxygen being partly derived, no doubt, from the air, and partly from plant life); thirdly, by the action of fish. He had no doubt upon that point, and he spoke with a knowledge of many of the important rivers in England and Ireland. In conclusion, he desired to ask the author a few questions.

First, admitting the complexity of the organic matter in potable water, and that the true test of the value of different processes for its estimation was consistency in their results, had the author ever attempted to prove or disprove such consistency; and, if so, could he favor the institution with the details of those experiments? Secondly, admitting his theory of rivers being such important agents in spreading disease, would he explain how it was that in outbreaks of cholera where towns had been affected along the banks of a river, the order of attack had been invariably up the river, and not down? Thirdly, would he explain, in view of his alarming picture, how it was that towns supplied with river water showed no greater general or zymotic death rate than towns supplied with deep well water; or if he stated that which was not true, would he bring forward facts to contradict it? Would he explain, further, how it was that in London the parts supplied by the Kent Water Company showed an almost iden-

tical general and zymotic death rate with those supplied by the waters of the Thames and the Lee? Fourthly, admitting that there might be germs in running water, could he adduce any evidence to show that under natural conditions of flow and contact with oxygen they were not amenable to the same laws as organic matter generally? He would only say that if the chemist desired to gain the respect of the engineer or of the sanitarian, he must not indulge in far-fetched and fanciful theories or hypotheses, but confine himself strictly to the arena of facts.

Dr. Thudichum said when important questions were concerned, and one had a strong conviction to state, it was not easy to find a form in which to make that conviction acceptable. Nevertheless, he hoped to make himself intelligible on some of the main points which he desired to illustrate. He congratulated the author on having made on the whole a clear, succinct, and practical statement. No doubt it required on his part a great

deal of courage as a chemist to come forward and tell his brother chemists that they were groping in the dark, and that their analyses were valueless. If chemical analyses of waters were to be discredited, Dr. Thudichum would feel much regret; but there was a great deal of truth in what the author had said. It had been stated by Dr. Tidy that he had latterly come to the conviction that Dr. Frankland's analysis of water was as good as his own. If the members had been present at the meetings of the Chemical Society, when that matter was discussed, they could hardly have believed what had since taken place. Neither having convinced the other as to the uselessness of his particular mode of analysis, they at last became friends, and said to each other, "Your analysis is as good as mine; let us embrace and be friends." What did those analyses mean? They ascertained that a certain amount of organic matter was present in water intended to be drunk, but they showed no more. The organic matter, for ex-

ample, contained in Thames water could not be shown to be noxious to health. Chemists had not shown at what particular concurrence of conditions they were to begin to consider water injurious which contained a certain amount of organic matter, and under what circumstances it was to be considered wholesome. Waters taken from sources like rivers always contained organic matter, because they were always flowing over large surfaces clothed by vegetation, living or dead, and under all circumstances there was a certain amount of dead, organic, vegetable matter present in watercourses. How innocent the organic matter of the river Thames was he had proved in this way. He had sent to the places where the water companies took their water, and caused to be collected a large amount of organic matter, carried it to his laboratory, infused it with distilled water, and allowed it to stand a certain number of hours. He then analyzed it, and found what he expected, that this distilled water had as-

sumed, with regard to organic matter, the properties of Thames water. He therefore maintained that the analysis of water, with reference to the quantity of organic matter contained in it was, hygienically speaking, of no value. The next point to which he desired to refer was the bearing of the results of biological and microscopic research on the subject under consideration. That led to the point on which the whole argument oscillated. Under what circumstances was water wholesome, and under what circumstances was it unwholesome? There might be waters which contained so much inorganic matter as to cause diarrhœa, but such waters would be so unpalatable that they would not be drunk. On the other hand, there might be waters perfectly clear and palatable in which the chemist would discover no appreciable amount of organic matter, and yet they would carry death wherever they were consumed. That was the biological aspect of the question, and in regard to that aspect microscopic art was

just as impotent as chemical art to determine whether water was wholesome or not. Then what test could be applied to ascertain the fact? There were various tests, some of which had been unpremeditated. For example, when in the East of London cholera swept along the river Lee and attacked twenty thousand persons, that was an experiment on a large scale. When again in the South of London two companies rivaled each other which should proceed in the most successful way to distribute cholera amongst their consumers, as in 1848 and 1854, other examples were made on a large scale. If another example was required, showing how water might be contaminated without microscopists discovering it, the case of the poisoning of Caterham Well might be taken, by means of which three hundred and fifty-two persons contracted typhoid fever, because a small amount of excrement from a sick person who was allowed to work in the well got mixed in the water. Under such circumstances it was neces-

sary to see with an eye which was not microscopic, and to apply a certain argument which was not chemical, but which was hygienic or medical. Water might be bright and brilliant, and yet contain the germs of death in it. It was well known that things might have organs and a certain chemical composition, and yet not be visible to the eye. Take the case of a minute drop of blood; put it on a microscopic slide, and add water to it. All the corpuscles were before seen to be red, and their shapes were distinguishable, but after the addition of the water the coloring matter was withdrawn, and no power of the microscope could make them visible. Here was a case in which an organized body of the diameter of $\frac{5}{1000}$ of a milimeter could be rendered invisible, and how much more might that be the case with a body having perhaps not $\frac{5}{1000}$ part of the diameter of a blood corpuscle? He referred to those germs which in the last thirty years had been proved to exist as the causes of zymotic diseases. He would refer, as an illustra-

tion, to the germ of the fowl-cholera. It was as distinct a germ as could be made out, visible under the microscope, having spores, still minuter particles, which were to the bacterium as the seed was to the plant. If those germs were preserved for a certain time in a closed tube, a cloud would at first be seen, but as the oxygen in the tube was removed and consumed, the germs assumed a different shape and appearance; they were lost to sight altogether. How were they to be found out? Not by the microscope, not by chemistry, but by taking a needle and dipping it into the liquid, which was perfectly transparent, and then inserting it in the cutaneous tissue of the fowl, and in a few days the fowl would be dead. It was impossible to experimentalize with water merely, so as to show whether it was wholesome or not. What then followed? What hygienists had always maintained, that water should be taken from natural sources which were neither contaminated nor contaminable, and those should be

the only sources of drinking water for communities and individuals. Could this proposal be carried out? Of course it could. In the neighborhood of London, for example, taking a circuit of 30 miles, 100,000,000 gallons of spring water could be found running every day, which would be amply sufficient to supply the culinary and drinking wants of London. In the neighborhood of Hertford, for instance, there was a spring yielding 10,000,000 gallons a day. It ran into the river Lee, and there would be no practical difficulty in taking it out of the river, and sending it direct to London, without allowing it to be contaminated by dung-boats and all the filth that accumulated in the river. The citizens of London, who first attempted to supply the city with water, did not go for river water, but for spring water, and it was for the conduction of spring water to London that they got their first Act of Parliament. In like manner, engineers should set about it now, everywhere getting all the spring water they could to

supply towns. They would find in every neighborhood a sufficient supply to satisfy the public wants. London, of course, would require a double supply, according to the proposal worked out by Sir Joseph Bazalgette, Mr. Easton, and Sir F. J. Bramwell, a proposal which had his greatest admiration. It should not be imagined that because it was strange it was unparalleled. In fact an example might be found in a town having much more limited means than London. He held in his hand a report by the Government of Würtemberg on the public water-supply of that kingdom, a kingdom which he believed was at the head of civilization in regard to that question. In the capital, Stuttgardt, there were two supplies, one of common water for watering the streets, filling baths, and flushing closets, and another for drinking and cooking. Numerous instances might be cited from that report of the care taken to supply even the lowest classes of the community. Even the villages on the highest mountains in the Raue Alb

were supplied with excellent spring water, to the extent of 60 liters per head per day. It was pumped to the height of 310 meters, and the pressure in the pipes was 75 atmospheres. If a small village of that kind could be supplied with pure spring water, would not the richest town of the richest nation in the world be able to get the same security against disease? The dangers threatening were very great. Perhaps not once in ten years would a river carry disease massively in its water, but if it did so once in a century it should be provided against. The water from the downs of Hampshire came filtered through hundreds of feet of chalk. It was of the greatest purity, cool, and having no organic contamination of any kind, and if it were taken through pipes to the consumer in London, under a system of constant supply, all danger would vanish; but if the towns continued to be supplied with water from rivers, there would certainly be, on some occasion or other, a failure of filtration, the intro-

duction of disease, and a repetition of the fearful and melancholy lessons of the last thirty years, during which one hundred thousand people had been crippled, and not less than twenty thousand had died from poisoned water. With the qualifications he had mentioned he had fully agreed with the author, and thanked him for having afforded an opportunity of discussing so important a question.

Mr. HOMERSHAM said for more than thirty years he had been in frequent communication year by year, with analytical chemists and microscopists in respect to the examination of water from different sources, to make selections for the supply of water for drinking and domestic uses. Many of those men, some of them personal and intimate friends of his own, as Clark, Graham, Lankester, Miller, Newport, Ronalds, Thomson, and Ure, were no more. From frequent communication with these, and still more frequent communication with others who remained, and from expérience gained in designing and carrying out various

works for the supply of different towns and places with water for domestic use, not only in the United Kingdom, but on the Continent of Europe, and places more distant, he was pretty familiar with what had been urged for and against waters derived from different sources. He made that statement to ask for indulgence, in case he should appear to speak somewhat dogmatically. With regard to the paper, it appeared to him that the word "previous" in the title had been unnecessarily added. For practical purposes, the point to be determined was the amount and the quality of sewage or other present injurious contamination, if any, in water for potable and domestic uses. Such water should be (1) at all seasons clear, transparent, bright, and, when seen in large bulk, pure blue, that being the natural color of uncontaminated water; (2) well aerated, holding in solution from 7 to 8 cubic inches of air per gallon, consisting of 2 or more cubic inches of oxygen and 6 of nitrogen; (3) it should

have at its source a uniform temperature equal to the average of the climate for the year, which in this country varied but little from 50° Fahrenheit; (4) should be free from living organisms, vegetable and animal, and from all dead decomposing organic matter, and should not dissolve lead; (5) should hold only a moderate quantity of mineral matter in solution, and thus be soft and not deposit a coating of lime or magnesia when being boiled. On the subject of potable water, he thought it was very questionable whether many persons drank cold water from choice. Where it was drunk at all, it was among the lower classes who unfortunately could not help themselves. When boiled it was drunk to a large extent, as in tea and coffee, and it was very largely used in culinary operations, and it was important that water used for such purposes should be such as did not deposit fur in boilers or tea-kettles. Uncontaminated spring- or other water, derived from a considerable depth below the sur-

face of the earth, was the only water that at its source had a normal even temperature at all seasons, summer and winter, and, as far as he knew, was also free from living organisms, vegetable and animal. It was also difficult to find any water but spring or subterranean that was at all seasons clear, transparent, bright, and when seen in large bulk, blue. Water derived from brooks or rivers, or from lakes, natural or artificial, varied in temperature at different seasons of the year, being comparatively warm in summer and cold in winter; it was more or less opaque, and when seen in bulk lacked the blue color peculiar to uncontaminated spring-water; it had in solution in warm weather less oxygen gas than spring-water; it held partly in suspension and partly in solution, after rains in hot seasons, manure washed from land and droppings from animals; and it also abounded in life, vegetable and animal, and was liable to inoculation by means of drains with the virus of specific diseases, causing ill-health and often

death to those who drank it. He agreed with the author in thinking that when samples of water from different sources were submitted to mere chemical analyses, it frequently happened that the results gave very little clue to their wholesomeness, or the contrary. He said very little clue, because there could be no doubt that chemical analyses often did give some clue, but in other cases it gave none whatever. Chemical, and only chemical, analysis could be relied upon to determine the quantity and quality of the gaseous contents of the water, the mineral contents and consequent hardness. The brightness, color and transparency of the water could be judged by the sight. Chemistry threw little light upon the nature, quantity, and quality of the organic matter that might be dissolved or mixed or lived in waters. Supposing, and this was common with river lake and other surface waters, a water to contain a large quantity of minute organisms, say several species of living plants and animals, and several hundreds

of each species in half a gallon, the chemist boiled all those plants and animals with the water, and after evaporating the liquid he weighed the residue, and then subjected it to a process of cremation. As the small animals and plants were composed of more than 90 per cent. of water, the loss in weight of the residue after cremation must be multiplied by 10 at least to arrive at their weight when alive. As to the names, or peculiar forms or qualities, wholesomeness or unwholesomeness, of the plants and animals, chemistry, to use the words of the author of the paper, was "powerless to help the sanitarian." Knowing that, it had been his practice during the last thirty years to submit samples of water, not only to an analytical chemist, and thus obtain all the assistance that could be had from chemical science, but to submit also samples to a competent microscopist and medical man well acquainted with the forms, names, habits, and other properties of the animal and vegetable organisms pervading many

waters. The practical importance of such microscopical examination would be evident from the following considerations. It had been well established that when certain microscopical plants of the nature of bacteria pervaded a water, to drink such water often gave rise to remittent fever, splenic fever, and pig typhoid. Chemistry was unable to discover these microscopic plants; but a competent medical practitioner acquainted with the properties and habits of those minute organisms could detect at least many of them and others of different kinds. In June, 1852, both the late Dr. E. Lankester and Dr. Redfern, the present professor of anatomy and physiology in Queen's College, Belfast, found from thirty-two to thirty-eight species of microscopic organisms, some plants, some animals, and some diatomaceæ, besides large numbers of each species in half a gallon of water, drawn direct from the supply pipes of the Lambeth Company (taking its supply at Thames Ditton), before entering any house cistern. In

1857 Dr. Hassall, in a report to the then President of the General Board of Health, stated that any water drawn direct from the mains of each of the waterworks under the provisions of the Metropolis Water Act, 1850, still contained considerable numbers of living vegetable and animal productions belonging to different orders, genera and species, but especially to the order or tribes annelidæ, entomostraceæ, infusoriæ, conferveæ, desmideæ, diatomaceæ, and fungi. Dr. Hassall stated that the examination was made in winter, and that other examinations should be made in spring, summer and autumn. No such further examinations, however, had been made by order of the Government. That, he thought, was a great dereliction of duty on the part of some department. Winter, it was suggested, was not the time to find the plants so well as summer and autumn, yet no other authorized examination had been made. The waters of the various companies were subject only to chemical examination. In the last Re-

port of the Government Water Examiner under the Metropolis Water Act, 1871, a chemical analysis was given by Dr. Frankland, another by Messrs. Wanklyn and Cooper, and another by Drs. Bernays and Tidy. In that report, there was no mention of microscopical examination. If microscopists were employed to examine the water month by month they would find out the species that were more frequent at one season than another, and ascertain in what water they abounded. It was well known by those who had paid attention to the subject, that many classes of those plants and animals indicated unwholesome water, and that these were mostly to be found in warm weather. It was true that Dr. Frankland, with his analyses, reported that the Grand Junction Company's water contained moving organisms, but no particulars were given; while in the reports of Messrs. Wanklyn and Cooper and of Drs. Bernays and Tidy the presence of any organisms was ignored. That reminded him that only the other

day a shareholder who wrote in the *Times* newspaper stated that the company was satisfied with the report of its chemists, because they did not mention any living organisms; but it was not because there were none, but because no microscopists had been employed to detect them. Surely if it was worth while to have the companies' waters chemically analyzed once per month by five professors of chemistry, it should be made a point to have at least one examination of the waters in a month by a competent biologist and microscopist. In obtaining samples of water from distributing pipes for determination of the organic contents, the water to be examined should be drawn not only direct from a main but near to the "dead end," as it was technically called, of a rider pipe, or to the dead end of a service main placed in a side street, for the organisms existed in much larger quantities near the dead ends of mains than in circulating mains. The creatures were so intelligent that where they found the water

quiet they went to live and breed. Chemists sometimes asserted that water had not been properly filtered. Filtration in some respects really injured the water in summer, because during the process there was collected on the top of the sand a further quantity of organic matter that became decomposed, and furnished pabulum for the insects. The author had stated that reservoir- or lake-water contained but a small quantity of organic matter, but he did not agree with that statement. It would be found by the Registrar-General's Returns that wherever lake-water was supplied to a town there was an excessive mortality. But, putting that aside, as there were many other things to cause mortality besides impure water, yet such things as the excreta of animals, liquid and solid, leaves and the like were unavoidably washed into the water. Water contamination in lakes also arose from the formation of mud on their unlined sides and bottoms. It was impossible to prevent the formation of this mud, which

was congenial to the production and growth of animal and vegetable life. The water from Loch Katrine and the water supplied to Manchester were full of dead organic matter and living organisms, especially in the summer. The author had further stated that very slight contamination took place in water when exposed in the open country; but he could not agree with that statement. He remembered having a large reservoir lined with cement on the South Downs, for the supply of Brighton. The water was perfectly pure when pumped from the wells and into the open clean reservoir, but in a few hours in the summer, there were masses of confervæ growing on the top of the water, and soon after a number of insects of different orders bred and flourished in it. It was a serious expense even to clear out the reservoirs and keep them clean in the summer. The evil could not be prevented except by roofing them over. Carbonic acid was given off from bicarbonate of lime, which formed the pabu-

lum that the spores of the confervæ required, and the consequence was the water was polluted though the open reservoirs were in the country. He had seen open reservoirs in a hot day when clouds of insects had been blown by the atmosphere into and upon the water in heaps. It was an entire mistake to suppose that water could be kept pure in an open lake or reservoir because it happened to be in the country. The temperature of the Thames in a hot summer was as high as 72°, and in the winter it was as low as 35°. Water, when it was warm, lost some of its oxygen, and plants and animalcules bred in it to a much larger extent than when it was cold. The loss of heat in winter, bringing the water down to within 3° of freezing point, rendered it liable to freeze readily in the consumer's pipes, and thus burst them. There was another point on which he disagreed with the author, that water to be purified must undergo a process of distillation by the heat of the sun. Water that fell on up-

lands composed of porous strata, such as sandstone, chalk, &c., was absorbed and percolated downwards often to great depths through the pores of the strata. A quantity of water was held in the pores by capillary attraction, and diffused through its mass. The varying density of the air brought the water thus held by capillary attraction in contact with changed oxygen, and by that process long-continued deprived the water of any organic matter it might have possessed. Supposing a depth of 18 inches of rain to go down through the surface in the course of a year, as the chalk strata were on an average more than 600 feet in thickness, and one-third of the bulk consisted of pores, it followed that it would require a depth of at least 200 feet of rain, or the produce of one hundred and thirty years, to saturate the pores.

Professor TYNDALL observed that Mr. Homersham had had very valuable experience in regard to the subject under consideration. He had gone with Mr.

Homersham to Canterbury, and seen the chalk-water there, and the mode of softening the water according to Clark's process. He did not know that he had ever seen a more beautiful experiment upon a large scale. He had also seen the same thing at the Chiltern Hills and at Caterham, where the works were under the supervision of Mr. Homersham. There was one point, however, in which he was inclined to differ from him, and to agree with previous speakers. He was rather doubtful as to the ability of a microscopist, even though he were a medical practitioner, to detect in water the germs that were chiefly damaging to man. He would take the case referred to by Dr. Thudichum, and a more lucid medical investigation he had never known. There was an outbreak of typhoid fever at Redhill and Reigate, where more than three hundred persons were attacked. Dr. Thorne went there, got hold of the tag-ends of his facts, fitted them together, traced them backwards, and finally came with the utmost certainty to a single in-

dividual who had been employed in sinking the well at Caterham, and whose excreta had infected the whole neighborhood. Imagine the diffusion of the infective matter through all those long pipes, and a medical practitioner trying with his microscope to find out the little infected particles. In his opinion it would be a hopeless task. In the case of that most virulent disease, splenic fever, which had been worked at so successfully by Pasteur, the germ was easily seen. It was a large bacterium. But there were bacteria that were not easily seen. He had, for instance, a cascade near a little house on the Alps, 7,000 feet above the sea, and although it was charged with water coming from the snow-fields of the Alps, if he took a speck of that clear water and infected an organic infusion with it, in forty-eight hours the infusion would become putrid and swarming with organisms. He once chose a piece of the clearest ice he could find, placed it under the receiver of an air-pump with perfectly moteless air

around it, and allowed it by fusion to wash its own surface. From the heart of that ice, clear as crystal, he took a quantity of water, and gave it to Dr. Burdon Sanderson, who found that it contained germs of bacteria just as effective in producing putrefacation as ordinary water. He should not, therefore, like to accept the notion that germs were so easily detected by the microscope. He agreed with Dr. Thudichum, that chemical analysis would afford but little information as to the deadliest things that might be in water, and that the microscopist could tell very little about them; but that the best way was to draw water supplies from sources where contamination could not come into play, and in that respect he desired to say that Mr. Homersham stood conspicuous among engineers.

Mr. Jabez Hogg remarked that, as a microscopist of some experience he agreed in part with what had fallen from Professor Tyndall as to what the microscope could do, and what it could not do.

He admitted that the microscope had never disclosed the kind of bacterium that would produce a specific form of disease, but he could not agree with him that the microscope could not detect the presence of bacteria. It could not perhaps detect the exact formation of the creature moving under the field of the microscope; but microscopists could say something was there a little beyond their ken, and medical men and physiologists could carry it a little further, and take some of the supposed infective germs, and produce a physiological action upon the blood of an animal, and in that way confirm the suspicion that there was something wrong with the water. As to the particular method to be pursued and carried out in researches of the kind, he was pleased to find the Local Government Board bringing its authority to the elucidation of this point. An independent body was taking steps that would tend to set the vexed question of contagion at rest. A very competent gentleman was proceeding to make a series

of experiments to ascertain what amount of significance could be attached to current methods of chemical analysis of potable waters. He took samples of water, purposely polluted them with stools of typhoid or enteric fever patients, and compelled animals to partake of them. The results already obtained were startling, and sufficient to confound some who were strong in their belief of chemical analyses, and of those who persisted in jumbling together the evidence of organic impurity and the evidence of unwholesomeness. In the first part of the paper, various ways had been mentioned in which water became contaminated. He desired to point out the great necessity for using precise terms in reference to such matters. Dr. Thudichum had spoken of spring-water. Spring-water was water that many persons would not like to drink. He supposed Dr. Thudichum meant water drawn from subterranean sources at great depths by an artesian well. If this were so, he might be permitted to refer to the inquiry into

the Molesey irrigation scheme. It would be remembered that the Molesey people wanted to irrigate certain lands with sewage, and it was discovered that the Lambeth Company was drawing 2,000,000 gallons of its water daily from a gravel-bed subsoil source at Molesey. This underground water was discovered when putting down conduits. The pipes were found to be passing through an immense body of water, and the engineer thought he could not do better than pump it up and use it, and call it spring-water. This was done for a considerable period, and it was supposed the Company were pumping deep well-water. The water was submitted to chemical analysis, and pronounced "perfectly pure and wholesome;" on closer investigation, it was found that the water was in a very bad and unwholesome state. In the course of the judicial inquiry Mr. Michael said: "This is neither more nor less than diluted sewage of a most dangerous nature?" The engineer replied, "Oh no, it is not, for it has been

filtered and submitted to our chemist, who pronounces it pure and wholesome water." Among the chemists who pronounced it to be pure and wholesome was, he thought, Dr. Tidy. It had apparently not entered into the calculation of any one, that in drawing subsoil water from an area of some extent (in this instance a radius of more than 1½ mile) the whole incidence of that area must be taken into account. Now, it so happened that at West Molesey it included seven hundred and seventy cesspools, all of which were being pumped dry, and mixed in with the Company's water. A Government investigation ended in putting a stop to that objectionable mode of drawing a supply of "spring-water."

Dr. Tidy said it was a mistake to suppose he had certified to the wholesomeness of this water, on the contrary, he had condemned it.

Mr. Jabez Hogg said he was glad to hear the statement of Dr. Tidy, but he knew that the chemists of the company

had expressed an opinion that the water was perfectly pure and wholesome. He could not for a moment doubt Dr. Tidy's word, but there were one or two points in connection with other of his statements which he desired to notice. He had contended that if the Thames River water had a run of a certain number of miles it would tend rapidly to oxidize all the sewage mixed with it. "His results," he said, "were in accordance with those of all the chemists who had examined and reported on the subject; and he also believed that the Thames in its flow of 130 miles as a definite stream did not acquire any increased proportion of organic matter." If Dr. Tidy had examined the water at Lechlade as well as 130 miles lower down, but of which he afforded no evidence, his remarks were apt to mislead. From the first part of his statement it would appear that the Thames was as pure at Hampton as at Lechlade, the water not having acquired any increased proportion of organic matter; but the

results he had published did not show the condition of the water in the river 130 miles below Lechlade; they merely showed its condition after it had passed through the company's filters. Looking, however, solely to the condition of the water after it had been filtered, and applying Dr. Tidy's own theories concerning the rapid destruction of organic matter, and which at Lechlade proceeded from a scantily populated district, and might be taken to be comparatively free from sewage, all organic matter would, according to his theory, have been destroyed long before it reached Hampton; whereas that which replaced it, must contain sewage contamination from numerous populous towns from Lechlade downwards. The organic matter, therefore, even if not large in amount, would be worse in quality, and the water, of course, inferior. In fact, all the towns situated on the banks of the Thames were constantly pouring in large quantities of sewage, and there could be no run of more than 100 yards, to say nothing

of 130 miles, where pollution was not going on day and night. Who then could undertake to say when and where some typhoid or malignant fever patient would not be sending excreta into the Thames in a course of 130 miles? Turn to the report of a chemist who differed from Dr. Tidy—the official water-analyst of the Government, Dr. Frankland, whose experience in such matters was beyond all question. He had spoken in his report of the improved condition of London water, which he said was due to the weather and to efficient filtration; but Dr. Frankland's opinions were still strongly adverse to the use of Thames water for drinking purposes, on the ground that it would not be safe so long as sewage found access to it. Actual danger might arise in the production of diseases believed to be propagated by organisms possessing a remarkable degree of vitality; and when seasons conducive to an expidemic outbreak supervened, it was imperatively necessary that water-pipes should not

become vehicles for the spread of disease. The important point of divergence between Dr. Frankland and Dr. Tidy, who were both working from the same data, consisted, not in any marked difference as to facts, but in a difference of opinion as to the import of those facts. That was a point which should be clearly understood and weighed when misleading chemical reports were issued to the public. Dr. Tidy of course fell back upon the Registrar General's Reports, as showing that there was no increase of deaths in London; but he omitted altogether to take into consideration how much London had advanced in its sanitation during the last twenty years; how much care had been bestowed by Officers of Health, not only in benefiting the poorer portions of London, by turning out the poor people and letting in light and air, but also in improving the health of London generally. There was scarcely a person, whatever might be his position in life, who had not benefited by what had been effected in that respect. He

agreed with the author in his general conclusions, and was ready to admit that he had done a great service in opening out so important a question.

Mr. W. Atkinson said it appeared to him that the whole force of the paper depended upon the question whether zymotic diseases were the result of the growth of living germs in the human frame. The author admitted that water, if it contained dead organic matter, in passing down a stream was purified, and he assumed, what Mr. Atkinson believed had never been proved, that zymotic diseases were dependent upon living organisms of such great vitality that they were almost indestructible. He knew that Professor Tyndall and Mr. Hogg were high authorities on the subject, but he did not know that there was anything to contradict the statement of Dr. Tidy that there was as yet no absolute evidence of living germs propagating those specific diseases. The question of chemical analysis, he thought, had been pretty well cleared up. The author had stated

that although chemical analyses did demonstrate the presence of organic impurity, yet it did not enable a decision to be made as to whether it rendered the water unwholesome. That had been fully borne out in a little work by Mr. W. Noel Hartley, Demonstrator of Chemistry at King's College, who stated at page 23: "Even in very unwholesome waters the amounts of organic matter are exceedingly small. The chemist can tell how much carbon and how much nitrogen this organic matter consists of, but he is powerless to say, by applying any distinctive test, that he is acquainted with the nature of the organic matter, and that it is such as will act as fever poison or as cholera poison."

Mr. Charles Ekin said that, at a recent discussion at the Chemical Society on that question, Professor Huxley pronounced an emphatic opinion that water might be as pure as possible from a chemist's point of view, and yet be most deadly; but he did not undertake to say as a physiologist that it was possible to

detect the organisms or organic matter contained in it. Mr. Ekin quite agreed with the author and Dr. Thudichum as to the little value to be attached to the determination of organic matter in water, because he had, over and over again, examined water that had undoubtedly given rise to typhoid fever, and found that it contained a very small amount of organic matter, and he had gone into districts where there could be no sort of contamination, and examined the springs, rivers, and brooks, in which he had frequently found large amounts of organic matter, that by no test could be distinguished from the organic matter in sewage. It was well to keep in view the fact that contamination was simply a question of degree. Dr. Thudichum would always go to springs, but he hardly realized the difficulty of getting pure spring-water and keeping it pure. Towns that were using springs for their supply were getting more and more alive to the necessity of buying land around the springs, to prevent the water from being contamin-

ated by high y-manured fields or market gardens. Nearly all the water used for drinking purposes in England must be more or less contaminated, because it was collected on surfaces highly cultivated and thickly populated. With regard to the question of previous sewage contamination, the author overstated the case when he said is was impossible to tell whether the nitric acid and ammonia present in any water had been derived from rain-water or from the soil through which the water had percolated. As a matter of fact it was easy to distinguish between the two, as the amount in rain-water did not exceed a certain very small percentage, and deducting this, the quantity derived from the soil was arrived at. Although the term "previous sewage contamination" was in some respects a misleading one, still there could be no doubt that the determination of the items included under this head afforded useful data in judging of the wholesomeness of drinking water.

Mr. Folkard in reply said, on the two

questions of the insufficiency of the present methods of chemical analysis, and the danger of using water which had been once polluted, he proposed making a few remarks. With regard to water analysis, the statement which provoked so much controversy, that chemists were powerless to discriminate between wholesome and unwholesome water, he would quote from Memorandum No. 3, on Drinking Water, issued by the Rivers Pollution Commission:—"The existence of an infectious property in water cannot be proved by chemical analysis." If chemists could not tell whether a given water was possessed of infectious power or not, he thought it was fair to say they could not tell whether it was wholesome or not, and therefore the statement in the paper was corroborated by the opinion of Dr. Frankland. Again, he agreed with the opinion frequently expressed by engineers, that a chemist should be able to give a decisive report on a sample from the results of his analysis alone, irrespective of the origin of the sample.

If a mineral was submitted for analysis, the chemist or assayer was indifferent as to where it came from or what depth it was obtained. He could report with certainty on the percentage of iron or copper, as the case might be, and if the processes of water analysis were reliable like those of inorganic analysis, water analysts could report with equal certainty whether a given sample was wholesome or not from the results obtained, irrespective of its locality or source. Whether water analysts were willing to give a report when thus left in the dark he left to engineers to decide. He knew that in at least one case this was not so, and that gentleman had had considerable experience, as he had it on good authority that several thousands of samples had passed through his hands. This seemed to show that neither Dr. Frankland, nor any other experienced water analysts, placed absolute reliance on the results of chemical analysis to show whether a water was wholesome or not, and consequently they agreed so far with the opin-

ion expressed in the paper. It was contended that the great question was, "What is the condition of the water now? not what was its condition fifty years ago, or 50 miles up-stream." This was perfectly true, but unfortunately it was a question which no water analyst could answer. The various processes of water analysis had one and all been shown on chemical grounds to be worthless, and he had endeavored to prove that they were worthless (as far as the power of indicating wholesomeness was concerned) by reasoning which required no technical knowledge to follow it, but simply the exercise of common sense. Eminent water analysts had brought forward apparently conclusive evidence of the worthlessness of all processes of water analysis except their own, and he was convinced that each one of those chemists was right, and begged to refer to their communications on the subject for proofs of worthlessness on chemical grounds. Further, he believed that the cause of the want of confidence of engineers in the results of

water analysis was due to the unavoidable employment of defective processes, in the absence of better and reliable ones. That this want of confidence existed he knew, because many of his friends were engineers connected with water-supply, and he ventured to think many could from their own experience corroborate the views at which he had arrived on theoretical grounds. If this were so, the sooner analysts owned it the better, instead of attempting to throw dust in people's eyes, and to bolster up defective methods by saying they had employed them so many thousand times. Consider the method of ascertaining the present condition of a sample of water by the permanganate of potash process. A measured quantity of water was put in a glass standing on a sheet of white paper, and it was noted how many drops of permanganate of potash were required to communicate a permanent pink color to the water. To give it its due, the process certainly had the advantage of simplicity, and after performing the experi-

ment some three hundred or four hundred times it might be a matter of question whether further repetition would greatly add to the operator's skill in water analysis. The sooner the water became pink, the less the amount of foreign matters present; but as to the nature of these substances every one was in the dark, and when it was inquired if Dr. Letheby, who invented the process, or Dr. Tidy, who used it, had established any definite relation between wholesomeness and permanganate, there was no answer. An intelligent lad could master the details of the process in half an hour, while, as before mentioned, the value of the result was admitted by nine-tenths of the analysts of the present day to be *nil.* He thanked Mr. Ekin for supplying an omission in the paper at page 6, line 15. After the words "by the rain in falling" it should have been mentioned that the amount of nitrogen existing as ammonia and nitric acid in rain being very small, anything in excess of the normal amount might, as stated

by Mr. Ekin, be fairly put down to animal or vegetable contamination. He could not agree with Mr. Homersham's remarks on hard water. The quantities were so small that it could make but little difference for dietetic purposes whether there were 5 grains or 40 grains of chalk per gallon. Besides many medical men were of opinion that lime in drinking water was essential to the health, at all events, of children, and therefore he could not but think it unfortunate that Dr. Frankland should return such harmless inorganic substances as chalk under the heading of impurities. Although perfectly correct from the chemist's point of view, it was liable to mislead the non-scientific portion of the community. The second question was as to the purification of rivers by natural means. Of course a great deal took place in this way, otherwise (as had been remarked) no one would be alive. Vegetation had a most beneficial influence, although he ventured to think that in nine months of the year in this dull

climate the effects could not be very energetic. It must also be remembered that vegetation was supported by inorganic materials, and that the organic matters contained in sewage must decay and be resolved into the salts of ammonia, carbonic and nitric acids, before they become available for the support of plant life. All this of course took time. The statement made by Dr. Tidy, however, was so extraordinary that it would well repay a little attention. It was to the effect that 10-miles flow was enough for purification (whatever that might mean). The velocity of the river might be assumed to be 2½ miles per hour, whence it followed, according to this theory, that in four hours purification had taken place. If Dr. Tidy meant that river beds showed no signs of sewage 10 miles below the outfall, the statement was probably true, but even that would depend on the ratio of the volume of sewage to the total flow of the river. But the assertion that sewage was decomposed in four or six hours was rather startling. Even

admitting this would be the case in the height of summer, during sunshine, and when vegetation was most active (and very few if any chemical actions, especially in dilute solutions, were complete in such a short time), what should be said about the winter months when sunshine was almost an event, and the temperature of the water was near the freezing point, the processes of vegetation and fermentation being nearly suspended? To say nothing of the fifteen hours' darkness of the winter night during which no purification by the aid of vegetation went on (light being essential), and in which time the sewage would flow with the stream 30, 40, or 50 miles. He submitted that the 10-mile estimate was far wilder and more fanciful than any assertions in the paper, in addition to which it was entirely at variance with facts. The Rivers Pollution Commission Report contained two analyses of the water of the Thames, viz., at Reading and at Shiplake paper-mill, and the result showed that after a flow of 4 miles the

organic carbon in the water was only reduced to about 6 per cent.; and even assuming that the diminution went on in the same ratio, a flow of at least 64 miles would be required in summer to effect decomposition, the date of the experiment being May 31st, 1873. As a matter of fact, however, such processes were almost invariably more and more sluggish towards the close, in addition to which there was absolutely no evidence to show that the morbific matters (he was half afraid to call them germs) were acted upon in the slightest degree. The above experiments should be pretty conclusive to Dr. Tidy, because the organic carbon was the constituent which agreed so very closely with some of his numerous determinations, and the correspondence of which with his own method he put forward as almost conclusive evidence of the reliability of both processes. After the severe remarks about germs, it was a comfort to him to reflect that he was not the only person who believed in their existence. To his

mind the evidence was as conclusive as of the presence of calcium, sodium, iron, &c., in the sun's atmosphere, and in both cases amounted to far more than a probability. To some minds, however, the fact of their not having been seen was to to the possibility of their existence, but it should at least be recognized that several eminent men believed in them. The town referred to in the paper in which an outbreak of enteric fever occurred about three years ago was Caterham. Dr. Thorne Thorne investigated the matter, and made a full report on the subject. The evidence was direct and conclusive that water contaminated with the dejecta of a workman suffering from enteric fever was the cause. An epidemic of typhoid occurred in the village of Lausen, near Basle, Switzerland. The case was investigated by Dr. Hägler, and experiments were made similar to those mentioned by Mr. Baldwin Latham, viz., by throwing about a ton of salt into the water of the stream opposite the cottage in which the first attack of ty-

phoid occurred. In two or three hours' time the water at the village became perceptibly salt, and this was corroborated by the proper test. Some 20 to 30 cwt. of flour were then thrown into the brook, to ascertain if the water was subjected to any filtering process. None of the flour (although well mixed up with the water) arrived at Lausen, conclusively proving that filtration, which was effective in stopping such comparatively coarse particles as those of flour, allowed the specific poison of typhoid to pass in sufficient quantity to strike down 17 per cent. of the population with the disease. A more detailed description had been given in the Proceedings of the Chemical Society, February 17th, 1876. It had been urged that the outbreak of fever at Caterham would not have occurred if the contaminated water had flowed in contact with the air as a river or brook instead of in closed pipes. Of course this was possible, but it was a mere assumption, unsupported by evidence; fortunately for sanitarians and the public the

Lausen case just described set the matter at rest, a mountain stream then being the vehicle of the typhoid poison. After this it would hardly be advisable to rely on germs being destroyed in flowing water. With reference to Mr. Baldwin Latham's remarks on the death-rate of London having slightly decreased, while the impurities in the river water had increased in quantity, it must be remembered that the sewerage system and the sanitary condition of the houses had undergone vast improvements, and therefore to his mind it was exceedingly disappointing that a far greater diminution in the death-rate had not been observed. The late Dr. Letheby pointed out that the real death-rate of London was probably very different from that shown by the Registrar General, the population being continually recruited by young people from the country; also the sick were, in as many cases as possible, removed into the country, and of course many thus died away from home. These causes probably made a difference

of at least 5 per 1,000, if not considerably more, and therefore there was no reason to boast of the corrected death-rate of the best sewered city in the world. The statistics of the cholera epidemic of 1854 conlusively showed the ill effects of a foul water-supply, the relative mortalities being as 13 to 4. The fact of the death-rate of the districts of the metropolis, supplied with river water, being the same as that of the Kent Company's district, was doubtless due to the greater number of recruits from the country who settled in the former area. If London were increasing eastward as rapidly as westward the cases would be parallel, and Dr. Tidy's conclusions would hold good, but in view of this great disturbing element (the influx of young people from the country into the western or river-water districts), such comparisons were almost valueless, merely showing that even with such great advantages the river-water area death-rate was not lower than that of the well-water area. He could not admit that the question of storm over-

flows was irrelevant. It was immaterial to the inhabitants of the lower towns on a river whether these overflows were theoretically necessary or not. The question to them was "did the sewage flow direct to the river in times of heavy rain?" In connection with this subject it should not be forgotten that the sewage thus discharged direct was in its foulest state, the great rush of water flushing the sewers and bringing with it accumulations of filth which had been collecting and festering, possibly for weeks. It would be a question of expense, viz., the construction of sewers in the upper towns large enough to carry off storm water without the necessity of using storm overflows *versus* the obtaining of the water supply of the lower towns from other sources than the river. There could be no doubt that the upper towns would feel it a great hardship to be obliged to spend two or three times as much on their sewerage system from this cause, and in view of the partial and imperfect nature of the remedy this extra

outlay would not be justified. He must also dissent from Mr. Latham's inference that low death-rates were the accompaniments of offensive states of rivers. It was probably a mere coincidence and could hardly be taken as proof of the harmlessness of such an abnormal state of things. The fact of malaria usually traveling up stream was irrelevant. It was prevalent in almost uninhabited countries, and was due to conditions of heat and drought simultaneously present in the upper and lower parts of a river. With reference to the effect of water containing the evacuations of cholera patients on the inhabitants of Birmingham, he did not think it was fair to expect an explanation of every case. That injurious effects had followed the use of such water (putting sentiment aside altogether) had been proved in England and on the Continent. It seemed to him that when an admittedly polluted stream was to be used as a source of water-supply the onus of proof of its innocuousness rested on those who

proposed it. It was not enough to show that no ill effects had been observed in particular instances. On the contrary, he thought two or three undoubted cases, of the transmission of disease by such waters, should be enough to condemn them as a class, and prevent wherever possible their use for domestic purposes. Besides, the mere idea was so loathsome that one almost wondered that an attempt should be made to defend it. If "drinking in a circle" were unobjectionable, then why have such refinements as sanitary inspectors, inspectors of nuisances, and food analysts? It certainly seemed inconsistent. The question had been put to him "admitting the presence of germs, was there any evidence to show that they were not amenable to the same laws as organic matter generally?" Here the necessity of extreme precision would be seen. The term organic matter was indefinite. If living organic matter were meant the answer would be self-evident, because germs were living organic

matter, and therefore must be amenable to the laws governing such matter. If, on the other hand, his interrogator meant dead organic matter, he replied that germs were no more amenable to the laws of dead organic matter than a living man was. Again, every biologist was aware that the lower the organism the more persistent was its vitality, as a rule, and therefore a living germ was at the very least quite as capable of resisting oxidation during a 10 or 100, or 1,000 miles swim down a river (water being its appropriate medium) as was a hen's egg for an equal time or during transport through an equal distance in its appropriate medium, the atmosphere; and he thought few people would doubt the capacity of a hen's egg to germinate after such an interval and such treatment. Under the circumstances he could leave the members of the Institution to decide which of two chemists was the more likely to gain respect, the one who, after ten years' experience in water analysis, had come to the conclusion that

the present methods were unreliable, and was willing to own it; or on the other hand, the one who tried to throw a halo of importance round a process admitted by nine-tenths of the analysts of the present day to be worthless, by stating that he had analyzed nearly four thousand samples by it. It would be equally logical to say that hanging for sheep stealing was a good law because it had (unfortunately) been carried out hundreds of times in this country. In conclusion he must thank the members for the kind way in which they had listened to the paper and to his remarks, and if it should be the means of directing still further attention to this important subject he should be extremely gratified.

CORRESPONDENCE.

Mr. H. Percy Boulnois said that the Water Works of the City of Exeter, of which he had charge, were the property of the Corporation. The daily supply amounting to 1,280,000 gallons, was pumped from the river Exe, the intake

being situated about 4 miles above Exeter and 12 miles below the town of Tiverton, the sewage of some ten thousand persons at this place being daily passed direct into the river in a crude state.

To ascertain how far this sewage contamination chemically affected the water, he took samples from different points in the river in August, 1880, and submitted them to Mr. F. P. Perkins, the public analyst of the City of Exeter, who examined them by the permanganate process and a modification of Professor Dittmar's carbon process. The following Table (see next page) embobied the results of these tests.

It would be noted, on reference to this Table, that the water at the intake was chemically nearly similar to that above Tiverton, and that this result was obtained gradually by the water on its journey. The Dart stream, however, seemed to pollute the water, there being a marked difference between samples 4 and 6; this was accounted for by the fact that the Dart rose on Exmoor, and

SPECIMENS OF WATER TAKEN BY MR. BOULNOIS FROM THE RIVER EXE ON AUGUST 16TH, 1880, AND SUBMITTED TO MR. PERKINS FOR ANALYSIS.

Number of specimen.	Where obtained.	Distance below Tiverton.	Amount of organic impurity in 100,000 parts. Oxygen consumed $\times \frac{c}{o} =$	Organic carbon yielded
1	Above Tiverton............	1 mile above...	.0718 × 2.27 =	.163
2	Below Tiverton............	100 yards below	.0873 × 2.81 =	.246
3	Ditto......................	2 miles "	.0929 × 2.93 =	.273
4	Bickleigh Bridge...........	3 " "	.0788 × 2.41 =	.190
5	In a stream joining the Exe called the Dart...	3¼ " "	.2070 × 2.11 =	.436
6	Below Bickleigh mill stream.	3½ " "	.0859 × 3.16 =	.272
7	Bourne Farm..............	5 " "	.080 × 2.70 =	.218
8	Tho netown above the weir..	8 " "	.0831 × 2.60 =	.218
9	At intake..................	12 " "	.0715 × 2.29 =	.164

although it could receive absolutely no sewage contamination, it was brown with peat, and this gave a bad analysis.

So far as Exeter was concerned, it was contended that the water at the intake was not unhealthily affected by the sewawe contamination of Tiverton, and this result might be attributed to the following causes: (1) The excessive dilution of the sewage with a large bulk of pure water. (2) The oxidation which the water underwent on its 12 miles journey from Tiverton, tumbling as it did over two weirs and rushing over many a shallow and stony bed. (3) The action upon the water by aquatic plants and weeds, and of the soil of the river banks and bed. (4) The constant evaporation from the surface of the water, and consequent molecular changes thus altering its character. (5) Other unknown causes possibly at work which made up the ever active processes of Nature's great laboratory.

The author questioned the reliability of chemical analysis to detect "previous

sewage contamination," but he did not appear to have given credit to the fact that, in a properly conducted analysis, no chemist relied upon one indication only, but that all the bearings of the analysis and history of the water were considered. If the analysts' evidence was to be doubted, much difficulty would be experienced by sanitary authorities in closing polluted wells or other impure sources of water supply; but hitherto reliance had always been placed upon such evidence, and he thought no sufficient proof had been adduced in the paper to shake public confidence. The question was one of grave importance, the health of a community being no doubt greatly affected by the character of its water supply; no hasty conclusion should therefore be arrived at in favor of deep well water. It might be that the terrible "diseases of the stomach and intestines" mentioned in the paper were due to contaminations in shallow well waters, or to the mineral substances found in most deep well waters, and not

from that source which Nature pointed out as the most convenient and proper from which to derive the water supply.

Mr. Edwin Chadwick, C.B., observed that there were particles from small-pox and other eruptive diseases, which were known to be distributed in hospitals within measurable distances. But these were imagined, but not proved, to be germs of specific diseases which spread to immeasurable distances, and which it was averred must be productive of the same diseases. These germs were alleged to be the cause of enteric fever, and when conveyed by water carriage must generate it. A disease did arise sometimes, with varying type, from the emanations from stagnant drains or sewers. But he never heard of any arising in such conditions along lines of sewer in accordance with the germ theory. In an address given at Croydon to the members of the International Medical Congress by Dr. Alfred Carpenter, adducing experiences in answer to the violent objections that had been made by

the advocates of chemical disinfectants, and other processes against sewage farms, on the grounds that they must receive and must spread the germs of infectious disease. Dr. Carpenter stated the result of his experience, to which he would direct particular attention: it was as follows:

"The non-infectious character of the excretions of those suffering from epidemic and infectious diseases when distributed upon a sewage farm is proved by the fact that there have been occasional outbreaks of infectious diseases in Croydon during the past ten years, including two epidemics of small-pox, several outbreaks of scarlet fever, occasional cases of diphtheria, and three periods of typhoid prevalence—two of which were distinctly connected with contamination of water supply in its distribution, and a third was distributed by means of milk. In the years 1875–76 the excreta of at least a thousand cases of enteric fever were utilized on the farm. In the majority of the cases the excreta were certainly not disinfected, and had they been capable of setting up the disease, some of the sixty-five persons at that time in the employ of the Local Board must have suffered from the infection. Cases which did arise were

not on the farm, or even in the majority of cases, near to it; they were on the hills, beyond the range even of subsoil water. The changes in sewage are not in any way similar to those which have been known to take place in poudrette and other particular forms of dried ordure. There is no doubt in my mind of the destruction upon sewage farms of the germs of mischief, which, when unaltered, may be capable of setting up zymotic disease. They are not preserved as they may be in dried ordure, or in other products in which so-called disinfectants have been used, which have simply preserved the germs from decay; but they are chemically and physically altered so that mischief cannot arise. This result has been also found to apply to the excreta of animals suffering from epizotic disease. During the past few years there have been several outbreaks of infectious pleuro-pneumonia in the Croydon district, the infection being brought from the Metropolitan Meat Markets. The cow-sheds in which the disease has arisen have drained into the Croydon sewers, and blood and excreta from the slaughtered animals have been washed down those sewers. The sewers have carried the morbid matter from the sheds to the farm; but there has been no corresponding disease among the cattle upon the farm."

To this he might add that similar demonstrations were presented by all well worked sewage farms. Moreover, insects generated and distributed in solid manures, and in stagnant semi-liquefied manures, were drowned by liquid manures in active circulation. It must follow that from continued exposure to such germs as those assumed that the health of those working on the sewage farms must be lower than the average, whereas it has been shown in a report to the Royal Agricultural Society that the health of the people working and living on the sewage farms was remarkably higher than the average.

Mr. C. E. De Rance remarked that the author, by grouping a series of well-known facts in a definite connection, had done useful work, in establishing the unassailable result, that the practical freedom of drinking water from organic impurity must be absolute to prevent the spread of zymotic disease. How this desirable condition was to be obtained was a difficult problem. Gravitation

supplies, derived even from the mountain slopes of Wales and the English Lake District, traversed only by mountain sheep, occasional tourists, shepherds and their dogs, were liable to receive the germs of entozoa, especially from the latter; while water supplies abstracted from rivers, even when all town sewerage was intercepted, received streams flowing past polluted farm yards, and the soakage from the offensive ditches with choked outlets, which so often surrounded them. In a gravitation supply absolute freedom must of necessity be impossible, but much could be effected, by making the separation of sewerage and storm water compulsory, not only in the drainage from cities and towns, but in the effluent water from country estates.

In water obtained from underground sources, whether from deep-seated springs, or wells, the chances of poisonous germs being left was very small, after the passage of the water through several hundred feet of porous rocks,

provided that the water had passed through the texture of the rock, but in many cases, the water had simply traveled, both vertically and horizontally, through open fissures formed by joints and faults, and this was probably the condition of many wells giving an exceptionally large daily yield of water, which had not been naturally filtered. In some other cases, deep bore holes had been sunk entirely in porous rock, in which every care was taken to exclude, and tube out, surface waters, but the water yielded was found to be polluted, percolation having taken place through cracks and fissures, connecting the surface with the saturated portion of the rock beneath. Of necessity wells reaching porous formations after passing through a zone of impermeable material were not open to this objection, and the chances of pollution were exceedingly small in the water yielded by them and by deep-seated springs. To increase the yield of these springs appeared to be a matter of the highest importance, for

should the construction of "dumb wells" become general, and the drainage of impermeable lands be artificially carried to porous strata beneath, whenever practicable, the supply of pure drinking water would not only be increased, but the absorption of excessive rainfalls would diminish the intensity of floods, and improve the dry-weather volume of the streams.

Mr. H. U. McKie knew one town in Wales which took its water supply from a river, when about one mile of extra piping would have given good spring water. Villagers near the river from which the water was taken would not use it, yet chemists pronounced it pure. He had recently had occasion to examine some works by a river side, and saw what he thought to be two sticks floating down the rippled surface of the stream; they appeared to be attached together by a string, and made curious bobbing motions, similar to a float on a fishing-rod when there was a nibble at the bait; on closer examination he found

it was a large salmon so covered with a fungoid growth as to be both pitiable and revolting, and he was told that the river was full of salmon thus affected. Now, as this disease also attacked trout, ells, and other fish, in the river, he thought it right to ask if water so contaminated could be a safe source of potable water supply for a town? He knew of two towns on this river which derived their water supply from it, and there might be others.

Mr. H. Robinson could not agree with the author in his sweeping condemnation of the use of river water unless taken near the source. However desirable it might be to obtain water free from the risk of contamination (and every engineer aimed at securing such a supply) in practice it would be impossible to meet the wants of the community; if the rule laid down were acted on. The enforcement of this rule would necessitate the abandonment of numerous sources of supply which failed to comply with these conditions, but which, al-

though subject to the risks referred to, had not produced any evil results. Probably the author, by enforcing an unreasonably high standard of purity, would create some of the evils which it was sought to prevent. If only water from deep subterranean sources or from streams above suspicion of contamination were to be used, a less abundant supply would be available than was now employed. The limitation of supply would arise from two causes, one being the difficulty of obtaining the necessary quantity of underground water, and the other being the cost of getting it. Where the cost of supplying a town was attended with heavy water rates, Mr. Robinson had found that the authorities were disposed to restrict the quantity used for sanitary purposes, such as flushing sewers, road watering, and the like. Such restriction would lead to insanitary results. The alarmist views entertained by the author were not supported by practical evidence. If the germs of contagious diseases had the vitality and

produced the mischief alleged, the evils attending the use of water subject to their influence would have been manifested. Without wishing to underestimate the risk of transmitting diseases by water, Mr. Robinson would expect to find some proof of the allegation in the case of a city like London. Obviously the water supplied by the metropolitan companies which took their supply from the Thames must be placed in the class of water of the dangerous kind; no contagious diseases, however, could be traced to its use. Frequent attempts had been made to connect cases of typhoid and similar diseases to the use of water supplied from the Thames, and he had on several occasions been engaged in examining into such cases. He had found (and the experience of others was to the same effect) that where water had caused illness it had been solely through the foul state of the cisterns and receptacles for storing it. The presence of filth of various kinds and dead animals accounted for the mischief. A constant

supply would remove this cause of danger.

Another view of the subject was worth referring to. Supposing water perfectly free from suspicion was to be insisted on for dietetic purposes, a duplicate supply would be required in many cases, such as has been proposed for London. Were this system to be adopted the inferior water would most probably be less pure than that previously supplied, inasmuch as it would be thought unnecessary to filter water intended to extinguish fires, water streets, or cleanse courts, and alleys. The germs of some contagious diseases were, according to the best medical authorities, even more capable of being introduced into the human system through the lungs than through the stomach. If, therefore, the dangers apprehended were really based upon reasonable grounds, the air instead of the water might become the medium for conveying the disease germs under the state of things that would then exist. Much inconvenience had

been experienced by engineers, owing to analytical chemists adopting different terms to express the results of their analyses. Mr. Robinson was continually having to deal with analyses in which similar impurities were described by different chemists in different terms. The adoption of a uniform nomenclature would be both convenient to those who had to act upon the results of chemical analyses, and would also remove one of the several grounds of difference that appeared to exist amongst chemists themselves.